Research on Evaluation Methods for Vendor Selection of Freeway Safety Facilities

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Abstract. Freeways are an important component of urban transportation systems, and the traffic safety facilities within their sections are crucial to ensuring the safe operation of freeways. With the progress of society, the transportation industry is also developing, and safety facilities are an important part of the industry of traffic, so the demand for safety facilities of freeway enterprises increasing, and the choice of safety facilities vendors plays a decisive role in the development of freeway enterprises. Uses a scientific and classical synthetic valuation method to estimate several freeway safety facilities vendors. Through the synthetic index analysis and the queuing methods with the calculated comparative position, the vendors are evaluated from both aspects of portrait and transverse, which provides reference for the selection of freeway facilities vendors.

Keywords: Freeways, Vendors, Comprehensive valuation, Safety facilities

1 Introduction

The development of the global economy drives the development of the transportation industry. While enjoying the convenient transportation brought by freeways, safety issues caused by road problems are becoming increasingly prominent [1]. After a road safety accident occurs, traffic safety facilities often become the focus of investigation, so the selection of safety facility vendors in the transportation industry should be more scientific.

As a classical evaluation method, the comprehensive evaluation method adopts a more systematic and standard method to evaluate multiple indicators and multiple individuals simultaneously. The main step is to establish an indicator system for evaluation, and then use certain method or model that analyzes existing data and makes a quantitative overall judgment about the things being evaluated. The queuing method based on estimating relative positions can sort objects according to their priority order under each indicator and the weight of each objective, and can horizontally compare different objects under the same indicator. The comprehensive evaluation and the queuing methods based on computing relative positions are substantially used in the freeway, comprising comprehensive evaluation of freeway maintenance, road quality,

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service area facilities, etc. The use of the comprehensive evaluation method to evaluate the business status of vendors can provide constructive reference for companies to choose vendors to a certain extent [2-4].

Currently, both domestic and foreign scholars are enthusiastic about conducting qualitative and quantitative analysis of relevant indicators for the list. Various financial performance basic indicators and financial analysis methods to study financial data of companies has significant significance in evaluating the current state of companies and predicting the future [5]. Therefore, selects three typical freeway safety facility vendors and compares their operating conditions with product safety conditions as indicators. By researching their relevant data in 2023, multiple indicators are selected to analyze and rank the operating conditions of the three companies by combining the comprehensive index and the queuing methods based on computed relative positions.

2 Evaluation Methods

2.1 Computing Relative Positions Based Queuing Method

The queuing method based on relative location estimation scheme is used to compare the operation of three freeway safety facilities vendors. Since require very large original data set, a decision matrix, that is, a numerical value for each attribute of each evaluation object, needs to be provided in advance. However, there are properties that do not provide a decision matrix. The decision-makers can provide only a priority for candidate partner with each attribute. Relative position based queuing rule is a good method to solve this kind of problem. In a word, here adopts the queuing method based on relative position estimation to indicators.

2.2 Comprehensive Index Method

The original intention of the comprehensive index method is to combine the weight factors of each indicator with their corresponding scores to obtain a weighted comprehensive score, which can easily obtain complete, comprehensive, objective, and comprehensive evaluation results for different entities or schemes [6].

3 Comprehensive Evaluation and Analysis of Freeway Safety Facility Vendors

3.1 Indicator Selection

For the selection of safety facility vendors, this study refers to the safety facilities with the highest purchase volume from multiple freeway construction units. From a systematic perspective, combined with the company's business situation and product sales, based on the principles of scientific and targeted, systematic and hierarchical, representative and operable, openness and stability, considering the characteristics of the valuation supplier[5-7], as well as the economic, social, terrain conditions, and traffic safety level of the area where the freeway is located, and combining with the application of similar valuation indicators at home and abroad, and referring to relevant research results [8-10], after induction, analysis, comparative research, synthetic analysis and consideration, As described in Table 1, a freeway traffic safety valuation index system has been established.

Table 1. Index System of Evaluation

Category	Index	Property	Unit	Weight
Business Situation Of The Vendor	Asset	Positive	RMB 100mn	0.1
	Operating Income	Positive	RMB 100mn	0.2
	Return on Capital	Positive	%	0.2
	Per Capita Profit and Tax	Positive	Yuan/person	0.1
Product Safety Situation	Product Safety Factor	Positive	%	0.2
	Product Fault Rate	Negative	%	0.2

3.2 Example Analysis

Data Sources.

Based on relevant research, evaluates six specific indicators, including operating income, accounts receivable, per capita profit tax, assets, ROC, product failure rate. Table 2 shows this complete process.

Table 2 shows the financial data and product quality data of three representative listed freeway safety facility vendors in 2023. The financial data is taken from Dongfang Fortune Network, and the product quality data is taken from the official website of China National Market Supervision.

Table 2. Indicator Evaluation

Vendor	Operating revenue	Prepaid accounts	Per capita profit and tax	Asset	Roc	Product fault rate
A	16.86	2.77	1.67	72.18	5.84	-5.43
B	9.078	37.8	6.69	335.8	4.1	-1.33
C	47.56	9.16	2.67	66.69	1.81	-3.5

Combining Valuation Methods Analysis.

Estimating relative positions based queuing.

We estimate relative positions with queuing method to rank A, B, C vendors by above indicators. Let them be (X1, X2, X3), and are denoted as (Y1, Y2, Y3, Y4, Y5, Y6). Compare the importance of attributes to obtain the target importance judgment matrix A, and then use the sum thest weight vectors. The weight is set as: ω = (0.1 0.2 0.2 0.1 0.2 0.2)T.

(1) Representation of priority relationship in the scheme

1) If $x_i \succ x_k$, it means "x_i is better than x_k", which means that if there are no external factors forcing decision-makers, they will only choose x_i and not x_k.

2) If $x_i \sim x_k$, it means "x_i is no different from x_k", which means that the decision-maker is equally satisfied with choosing x_i or x_k.

3) If $x_i \approx x_k$, it means "x_i and x_k are incomparable", which means that decision-makers will not choose x_i and x_k together, and the two may be equivalent.

(2) The 0-1 matrix P of the priority relationship $P=\{p_{ik}\}_{m\times m}$

$x_i \succ x_k :\rightarrow p_{ik}=1$ and $p_{ki}=0$;

$x_i \sim x_k :\rightarrow p_{ik}=1$ and $p_{ki}=1$;

$x_i \approx x_k :\rightarrow p_{ik}=0$ and $p_{ki}=0$.

Tables 3 to 8 fully depict the detailed construction process of the priority relationship matrix, and the results in the table can clearly describe the differences in priority comparison results.

Table 3. Matrix of y_1 analysis

Scheme	1	2	3
I	1	1	0
II	0	1	0
III	**1**	**1**	**1**

Table 4. Matrix of y_2 analysis

Scheme	1	2	3
I	1	0	0
II	1	1	1
III	**1**	**0**	**1**

Table 5. Matrix of y_3 analysis

Scheme	1	2	3
I	1	0	0
II	1	1	0
III	**1**	**1**	**1**

Table 6. Matrix of y_4 analysis

Scheme	1	2	3
I	1	1	0
II	0	1	0
III	**1**	**1**	**1**

Table 7. Matrix of y_5 analysis

Scheme	1	2	3
I	1	1	1
II	0	1	0
III	**0**	**1**	**1**

Table 8. Matrix of y_6 analysis

Scheme	1	2	3
I	1	0	0
II	1	1	1
III	**1**	**0**	**1**

(3) Determine each plan for (x_i, x_k)

(i) Add up the weights of each target j of $(x_i \succ x_k)_j$, denoted as $\omega(x_i \succ x_k)$, similar to $\omega(x_i \prec x_k)$, $\omega(x_i \approx x_k)$.

$$\omega(x_i \succ x_k) = \sum_{j \in (x_i \succ x_k)_j} \omega_j \tag{1}$$

$$\omega(x_i \prec x_k) = \sum_{j \in (x_i \prec x_k)_j} \omega_j \tag{2}$$

$$\omega(x_i \approx x_k) = \sum_{j \in (x_i \approx x_k)_j} \omega_j \tag{3}$$

(ii) The mathematics scheme for (x_i, x_k), $1 \geq \sigma \geq 0$. σ express the importance that is indistinguishable between x_i and x_k in the decision.

$$A_\sigma(x_i, x_k) = \frac{\omega(x_i \succ x_k) + \sigma \cdot \omega(x_i \approx x_k)}{\omega(x_i \prec x_k) + \sigma \cdot \omega(x_i \approx x_k)} \tag{4}$$

From Table 3 to Table 8, it can be analyzed that the weight of X_1 is superior to X_2, the value is 0.1 + 0.1 + 0.2 = 0.4. The weight of X_1 is inferior to X_2, the value is 0.66666667. Taking A=1.2, σ=0. The scheme for (X_1, X_k) can be calculated as

$$A_\sigma(x_1, x_2) = \frac{\omega(x_1 \succ x_2)}{\omega(x_1 \prec x_2)} = \frac{0.4}{0.6} = 0.66666667 << 1.2$$

X_1 is better than X_3 with a value of 0.2, while the weight of X_1 is worse than X_3 with a value of 0.1 + 0.2 + 0.2 + 0.1 + 0.2 = 0.8. Taking A = 1.2, σ = 0. The overall quality index of the solution for (X_1, X_k) can be calculated as

$$A_\sigma(x_1,x_3)=\frac{\omega(x_1 \succ x_3)}{\omega(x_1 \prec x_3)}=\frac{0.2}{0.8}=0.25<1.2$$

X_2 over X3 is 0.9 which is equal to 0.2 + 0.2 + 0.1 + 0.2 + 0.2, and the weight of X_2 over X_3 is 0.1. Taking A = 1.2, σ = 0. The overall quality index of the scheme for (X_1, X_k) can be calculated as

$$A_\sigma(x_2,x_3)=\frac{\omega(x_2 \succ x_3)}{\omega(x_2 \prec x_3)}=\frac{0.9}{0.1}=9>1.2$$

(iii) Set the threshold $A \geq 1$ and determine the overall quality of the schmeme

$A_\sigma(x_i, x_k) \geq A :\rightarrow x_i \succ x_k$,

$1/A < A_\sigma(x_i, x_k) < A :\rightarrow x_i \approx x_k$

$A_\sigma(x_i, x_k) \leq 1/A :\rightarrow x_i \prec x_k$

Table 9 presents the relationship matrix of the whole priority of scheme I, II, and III.

Table 9. Overall priority relationship matrix

Scheme	1	2	3
I	1	0	0
II	1	1	1
III	**1**	**0**	**1**

(4) Calculate Queue Indication

The value of the queue index is

$$v_i = r_i - q_i \tag{5}$$

r_i is the count of directional arcs pointing outward from x_i;

q_i is the count of directed arcs pointing towards x_i.

v_i is synchronized with the shortcomings of x_i, in other words, each scheme can be evaluated based on the size of v_i, that is

$$v^* = \arg\max\{v_i\} \tag{6}$$

From this, it can be calculated that v_1=-1, v_2=1, v_3=0. The ranking of the three companies is $X_2 \succ X_3 \succ X_1$.

Comprehensive index.

The first step is separately to compute the positive and negative mean values of x_j, hereinto n is the count of objects, m is the count of index; x_{ij} is the j-th index value of the i-th object, n_j^+ describes the count of objects with non-negative values for the j-th index, and n_j^- represents objects count of negative values for the j-th index.

$$\bar{x}_j^- = \frac{1}{n_j^-} \sum_{x_{ij} < 0} x_{ij} \tag{7}$$

$$\bar{x}_j^+ = \frac{1}{n_j^+} \sum_{x_{ij} \geq 0} x_{ij} \tag{8}$$

Second step is to define the dimensionless x_{ij} and refer to k_{ij} as the conversion index of x_{ij}.

$$k_{ij} = \frac{x_{ij}}{\bar{x}_j^+} \times 100, x_{ij} \geq 0 \tag{9}$$

$$k_{ij} = \frac{x_{ij}}{\left|\bar{x}_j^-\right|} \times 100, x_{ij} < 0 \tag{10}$$

The results in Table 10 depict the conversion of various indexs for these three different vendors of A, B and C, which were gotten from above calculation-flow.

Table 10. Various vendors' indicators

Vendor	**Operating revenue**	**Prepaid accounts**	**Per capita profit and tax**	**Asset**	**Roc**	**Product fault rate**
A	68.82	16.71	45.42	45.62	149.11	-158.77
B	37.05	228.03	181.96	212.23	104.68	-38.89
C	194.13	55.26	72.62	42.15	46.21	-102.34

The third step is to get the synthetic index ki, which is the average value of the conversion index for each vendors.

$$k_i = \frac{1}{m} \sum_{j=1}^{m} k_{ij}, i = 1,2,3,...,n \tag{11}$$

Computing with the above steps, the synthetic index of various indicators for the three different vendors above in Table 11 can be obtained.

Table 11. Comprehensive indicators

ID	Vendor	Composite Index	Order
I	A	28	3
II	B	121	1
III	**C**	**51**	**2**

With the synthetic index method get the results of valuation in Figure 1.

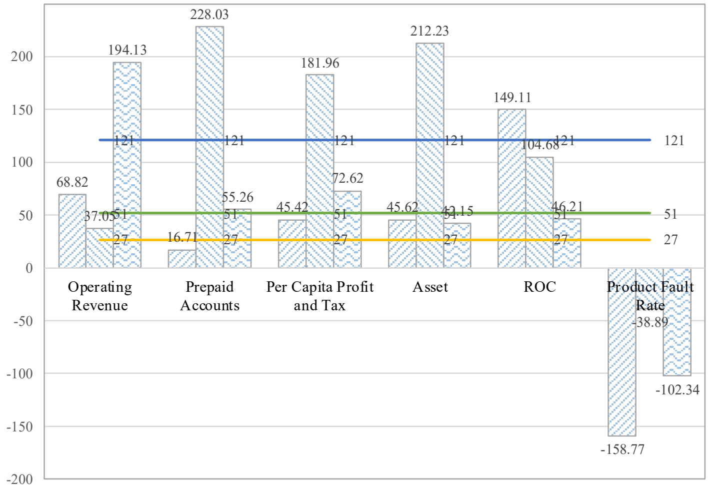

Fig. 1. Comprehensive index method valuation results

4 Conclusion

This paper proposes a synthetic valuation method for the synthetic use of two system indicators. By syntheticly applying different valuation methods, it is possible to more scientifically, objectively, and reasonably evaluate the operational status of the enterprise, and draw the conclusion that Vendor C is superior to Vendor A and superior to Vendor B. Limitation is that the complexity of constructing the indicator system is relatively low, and the complex organizational environment and market conditions require flexible adjustment of the indicator system to adapt to changes.

It should be noted that due to the large count of vendors on freeways, the vendors for different types of facilities also vary. Therefore, the next step of this study will focus on studying more types of supplier valuation methods, while continuously improving the indicator system and striving to achieve multi-dimensional and objective supplier valuation.

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